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Analysis Methods For Photovoltaic Applications

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The Solar Energy Research Institute

The Solar Energy Research Institute (SERI) was created by Congress in 1974 to provide the country with a national center of excellence dedicated to serving the needs of the public and industry in the development of solar energy. SERI began operations in July 1977, in Golden, Colorado. It is operated by the Midwest Research Institute for the U.S. Department of Energy (DOE). The primary mission of SERI is to function as the U.S. Department of Energy's lead institute for solar energy research, development, and application.

For information on the general operations of SERI, contact:

Public Information Office
Solar Energy Research Institute
1536 Cole Boulevard
Golden, Colorado 80401
(303) 231-1000

Other publications in this series include:

Analysis Methods for Wind Energy Applications (SERI/SP-35-231)
Analysis Methods for Solar Heating and Cooling Applications (SERI/SP-35-232)

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Analysis Methods for Photovoltaic Applications

Photovoltaics is one of the more attractive forms of electrical power generation by a renewable energy source because of its simplicity. Photovoltaic devices convert sunlight directly to electricity with no moving parts, no waste production, and minimal performance degradation over long periods of time. Their modular nature makes them ideal for electrical applications of virtually all sizes. Presently, photovoltaic modules can be found powering a myriad of small, remote applications. When the cost of other methods of electrical generation includes construction of power lines or the fuel and maintenance associated with a motor generator set, photovoltaic power can often be cost-competitive in such applications. In addition, as the cost of photovoltaic modules and other related components continues to decrease, the applications for which they become competitive include residences, small buildings and shopping centers, and perhaps even central power generating stations.

Because photovoltaic power systems are being considered for an ever-widening range of applications, it is appropriate for system designers to have knowledge of and access to photovoltaic power system simulation models and design tools. This brochure gives brief descriptions of a variety of such aids and was compiled after surveying both manufacturers and researchers. This list does not include all existing design tools—only those identified as being readily available to potential users. Information on other computational methods not included here can be found in "Survey of Currently Used Photovoltaic Simulation Methods," by J.L. Watkins, SERI/TR-35-224, Solar Energy Research Institute, Golden, Colorado.

It is intended that this document be periodically reviewed and updated. Persons knowing of models or tools not discussed in this brochure are asked to contact the Design Tool Manager, Market Development Branch so that future versions will contain the current state-of-the-art information on photovoltaic analysis methods.

Services Available Through Photovoltaic Module Manufacturers

Each firm listed here provides engineering design services, through Applications Engineers, for prospective customers, usually at no cost. Most firms use small computer programs for design and analysis. Generally, these programs and procedures have been developed for small, remote applications; a conservative design philosophy with large safety margins is assumed. Typical information required and supplied by the various manufacturers includes:

Calculation Methodology

1. Based on ampere and ampere-hour calculations
2. Based on average daily solar input on a monthly basis

Input Requirements

1. Site location (latitute, longitude)
2. Average daily load (kWh)
3. Unique conditions (e.g., extreme cold temperatures)

Output Features

1. Array size (square feet)
2. Array tilt angle (degrees)
3. Battery capacity (ampere hours)
4. Estimated monthly performance (kWh/mo)

Photovoltaic Module Manufacturers Offering Engineering Design Services

ARCO Solar, Inc.
Arthur I. Rudin
20554 Plummer Street
Chatsworth, CA 91311
213/998-0667

Motorola-Semiconductor Group
Dick Keller
Mail Drop A-110
5005 E. McDowell Road
Phoenix, AZ 85008
602/244-5459

Sensor Technology, Inc.
Testa Beeli or Otto Weber
21012 Lassen Street
Chatsworth, CA 91311
213/882-4100

Solarex Corporation
Tony Clifford
1335 Piccard Drive
Rockville, MD 20850
301/948-0202

Solar Power Corporation
John Sherwood
5 Executive Park Drive
Noth Billerica, MA 01862
617/935-4600

Solar Energy Systems, Inc.
Bill Kaszeta
One Tralee Industrial Park
Newark, DE 19711
302/731-0990

Optical Coating Laboratory, Inc.
Don Home
15251 E. Don Julian Road
City of Industry, CA 91746
213/968-6581

Specific Analysis Tools and Services

The following tools and services were developed for specific purposes related to photovoltaic system design and analysis. Most were developed for specific tasks related to photovoltaic systems research. Some provide detailed simulations of proposed photovoltaic system performance; still others are used to perform economic assessments of photovoltaic systems.

Summary of Analysis Tools and Services

Program Name	Performance Results Output			Economics Output				Computer	Program/User Manual
	Average Daily *	Hourly	Transient (μsec→hours)	Breakeven Capital	Life-cycle Cost	Busbar Energy Cost	O&M		
SIMWEST		●						CDC 6600 UNIVAC 1108	●
PVTAP		●	●					CDC 6600	●
SOLCEL		●			●	●		CDC 6600	●
ASMOD/DISLIFE		●		●	●	●			
BCL-SOLCEL/CONCEL		●		●	●	●		CDC 6600 CYBER 73	
Lifetime Cost and Performance Model		●			●	●	●	IBM 360/370	● (7/79)

Note: All programs are currently available at nominal or no cost from the contact person listed in the individual program description.

* Performance simulation methods that use average daily data are available through the services of the listed photovoltaic module manufacturers.

SIMWEST

This is a general purpose computer simulation program developed by Boeing Computer Services (BCS). Specialized routines, which model photovoltaic subsystems for use with SIMWEST, have been developed under contract to DOE and NASA. The entire SIMWEST code with the photovoltaic subroutines is available at nominal cost from BCS in either a CDC 6600 or UNIVAC 1108 version. The most expeditious means of access, however, is through the BCS time-sharing system. Documentation on SIMWEST is now available and documentation on the photovoltaic models will be available in May 1979.

Calculation Methodology
1. Hourly simulation
2. Based on energy balances and efficiencies

Input Requirements
1. Hourly direct normal and total horizontal insolation, ambient temperature (Typical Meteorological Year data available)
2. Hourly load data
3. System parameters (Flat-plate or concentrating collectors, power conditioning, battery storage)

Output Features
Tabular or printer plot output of hourly performance

Contact
Tony Warren
Boeing Computer Services Company
Energy Technology Applications Division
565 Andover Park West
Tukwila, WA 98188
216/575-5095

Larry Gordon
NASA Lewis Research Center
21000 Brookpark Road
MS 500-202
Cleveland, OH 44135
216/443-4000 X6943

PVTAP

BDM Corporation has developed the PhotoVoltaic Transient Analysis Program (PVTAP) under contract to Sandia Laboratories. This code, based on BDM's general-purpose network analysis code, NET-2, is designed for the study of transient effects and non-uniform ilumination on arrays and systems. This large computer code was designed to run on a CDC 6600 and can be obtained for a nominal charge from Sandia Laboratories. Detailed documentation is available.

Calculation Methodology
1. Transient solution of electrical network equivalent models including insolation, temperature, voltage, and current as state variables
2. Models the time response of any temperature, voltage, current, power, or cell failure condition
3. Includes models for cells, modules, thermal modules, collectors, and power conditioning

Input Requirements
1. Variable meteorological inputs: short duration transients up to daily totals
2. User defined load data
3. Contains library of device models; users may specify others

Output Features
Time dependent response in tabular or graphical form

Contact
R.M. Turfler
BDM Corporation
2600 Yale Boulevard, S.E.
Albuquerque, NM 87106
505/843-7870

Calvin Rogers
Division 4719
Sandia Laboratories
Albuquerque, NM 87185
505/264-2387

SOLCEL

Sandia Laboratories has developed a computer program, SOLCEL, specifically for simulating photovoltaic system performance. The code was developed on a CDC 6600. The source code and programming manual are available for a nominal charge from Sandia Laboratories.

Calculation Methodology

1. Based on hourly simulation
2. Models fixed and movable/concentrating modules, energy storage, power conditioning, and temperature effects
3. Based on energy balances and efficiencies
4. Economic analysis available

Input Requirements

1. Hourly direct normal and total horizontal insolation, wind speed, ambient temperature (SOLMET) data
2. Hourly load data
3. Subsystem sizing and efficiencies
4. Capital costs, lifetimes

Output Features

1. Hourly performance estimates in tabular form
2. Economic data including life-cycle costs and busbar energy costs
3. Subsystem sizing optimization

Contact

Ed Hoover
Division 4716
Sandia Laboratories
Albuquerque, NM 87185
505/264-7315

ASMOD/DISLIFE

JBF Scientific has developed and is currently using two computer models to evaluate the performance and economics of photovoltaic systems. The first is Annual Savings MODel (ASMOD), which evaluates the performance and estimates the annual savings of user-owned photovoltaic systems. The second is the DISpersed LIFE-cycle (DISLIFE) economic model, which evaluates the life-cycle economics to predict a system value for either residential or commercial owners. JBF will operate both codes under contract.

Calculation Methodology

ASMOD: Hourly simulation of system performance
DISLIFE: Economic model calculates break-even capital cost

Input Requirements

ASMOD:
1. Hourly direct normal and total horizontal insolation
2. Hourly load data
3. System sizing and efficiencies

DISLIFE:
1. Results of ASMOD runs
2. Economic parameters

Output Features

ASMOD: Simulated hourly performance in tabular form
DISLIFE: Break-even capital cost, costs, and savings

Contact

W. Neal
JBF Scientific Corporation
2 Jewell Drive
Wilmington, MA 01887
617/657-4170

BCL-SOLCEL/BCL-CONCEL

Battelle Columbus Laboratories has developed two computer programs which perform detailed hourly simulation of photovoltaic system performance and detailed economic analysis for private and utility-owned systems. BCL-SOLCEL models flat-plate photovoltaic systems, and BCL-CONCEL models passively cooled, concentrating photovoltaic systems. Both codes were developed for Sandia Laboratories on government contract. No documentation is available; however, both codes can be run on a use-charge basis by Battelle.

Calculation Methodology

1. Hourly simulations are calculated based on energy balances and efficiencies
2. Codes model temperature, shading, and reflectance effects
3. Codes model projected cash outlay and inflows over system lifetime

Input Requirements

1. Hourly meteorological data including total horizontal insolation
2. Hourly load data
3. Subsystem sizing and efficiencies
4. Total capital and operation and maintenance costs
5. Other economic parameters

Output Features

Hourly values of any selected variables plus economic data in tabular form

Contact

George H. Stickford, Jr.
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201
614/424-4810

Lifetime Cost and Performance Model

This computer model, under development at Jet Propulsion Laboratory with scheduled completion in July 1979, models the electrical and economic performance of photovoltaic systems over their lifetime. The code, written in SIMSCRIPT for use on an IBM 360/370 series computer, will be available at nominal cost from JPL.

Calculation Methodology

1. Hourly simulation
2. Based on original performance parameters of modules
3. Models degradation mechanisms
4. Models life-cycle costs, discounted cash flow

Input Requirements

1. Hourly meteorological data including direct normal and total horizontal insolation
2. Hourly load data
3. Subsystem sizing and efficiencies
4. Financial parameters

Output Features

1. Hourly simulated performance
2. Life-cycle cost, busbar energy cost
3. Generates maintenance schedules

Contact

Chester Borden
Jet Propulsion Laboratory
Building 506-316
Pasadena, CA 91103
213/577-9542

Note: Jet Propulsion Laboratory has developed several other programs for use in various aspects of photovoltaic module manufacturing and system design. All are available at nominal or no cost.

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